Concrete Durability
Dr Peter Taylor

Outline

- What is durable concrete?
- Why does concrete fail?
- What can we do about it?

What is durable concrete?

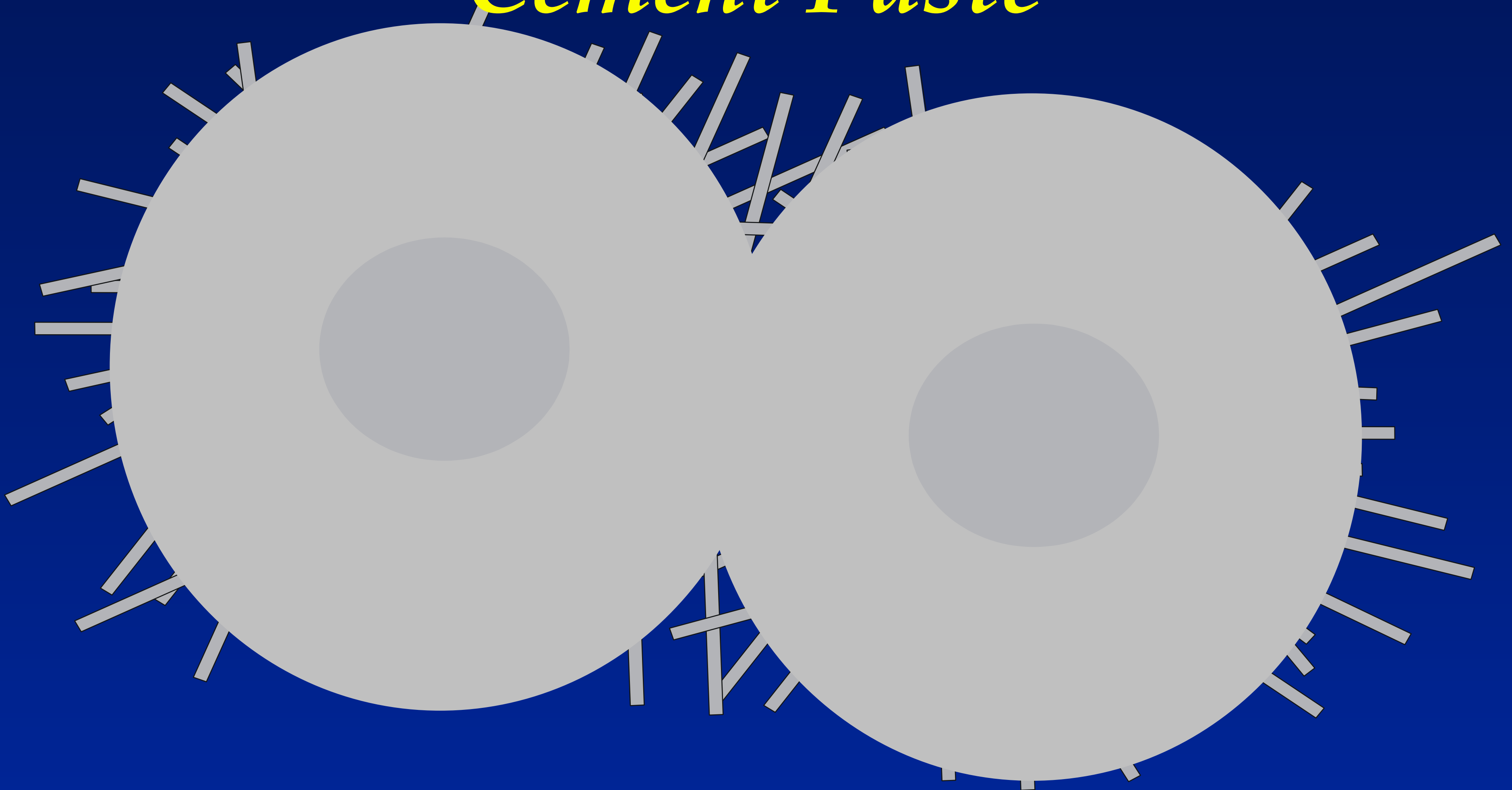
- The right
  - Materials
  - Proportions
  - Workmanship
- For the environment
- So that it lasts for the intended time

Concrete

Portland Cement

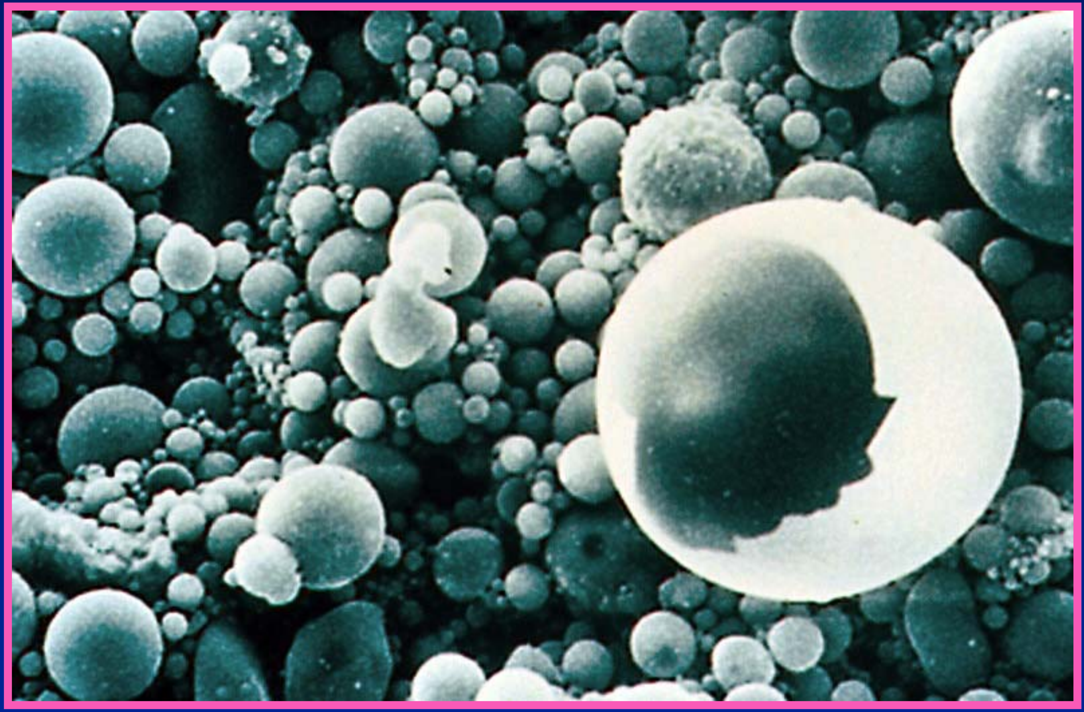
- Traditional cements (Type I to Type V)
- Blended cements

Microstructure of Hydrated Cement Paste



Pozzolans

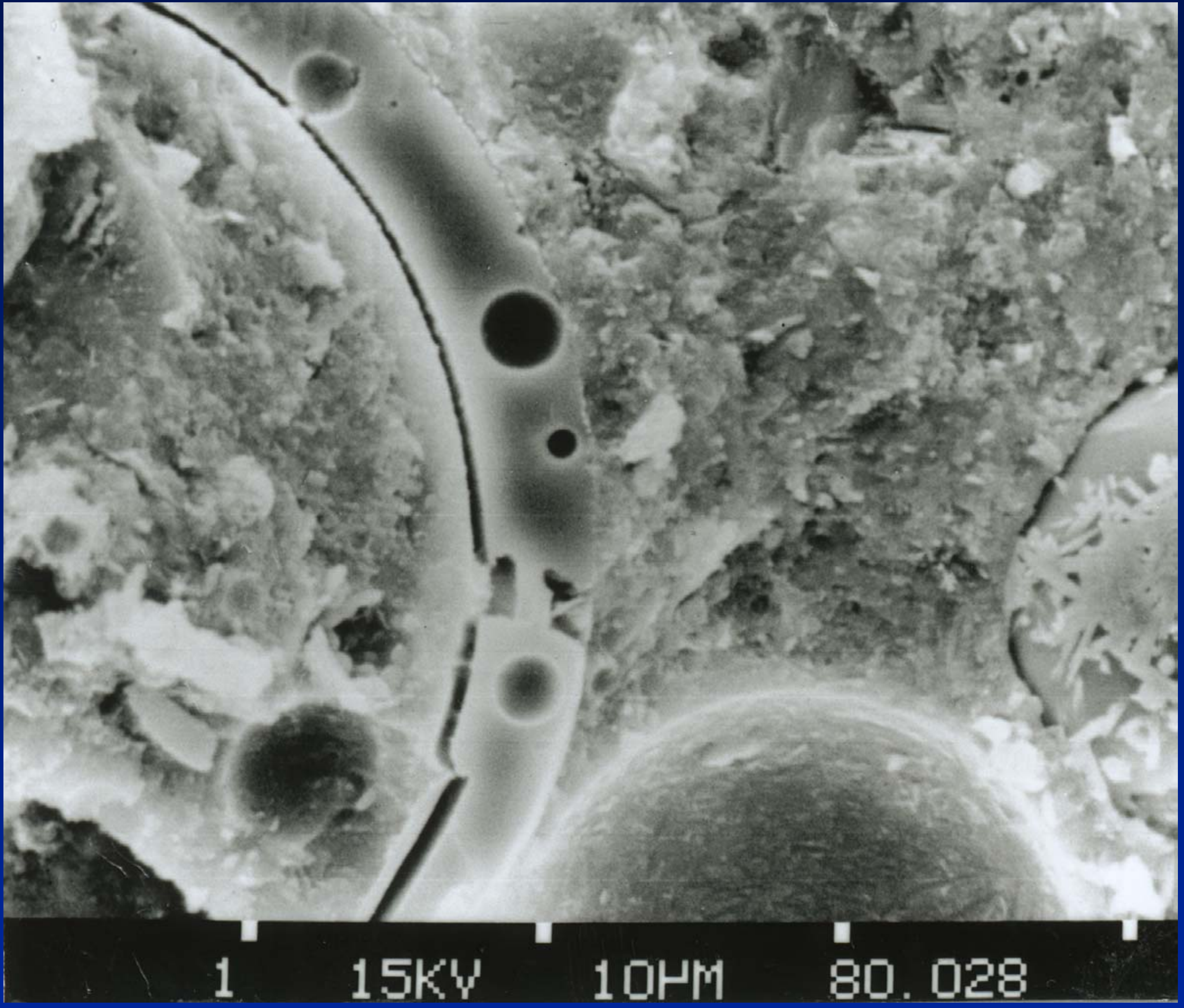
- Slag (GGBFS)
- Fly ash
- Silica Fume
- Metakaolin



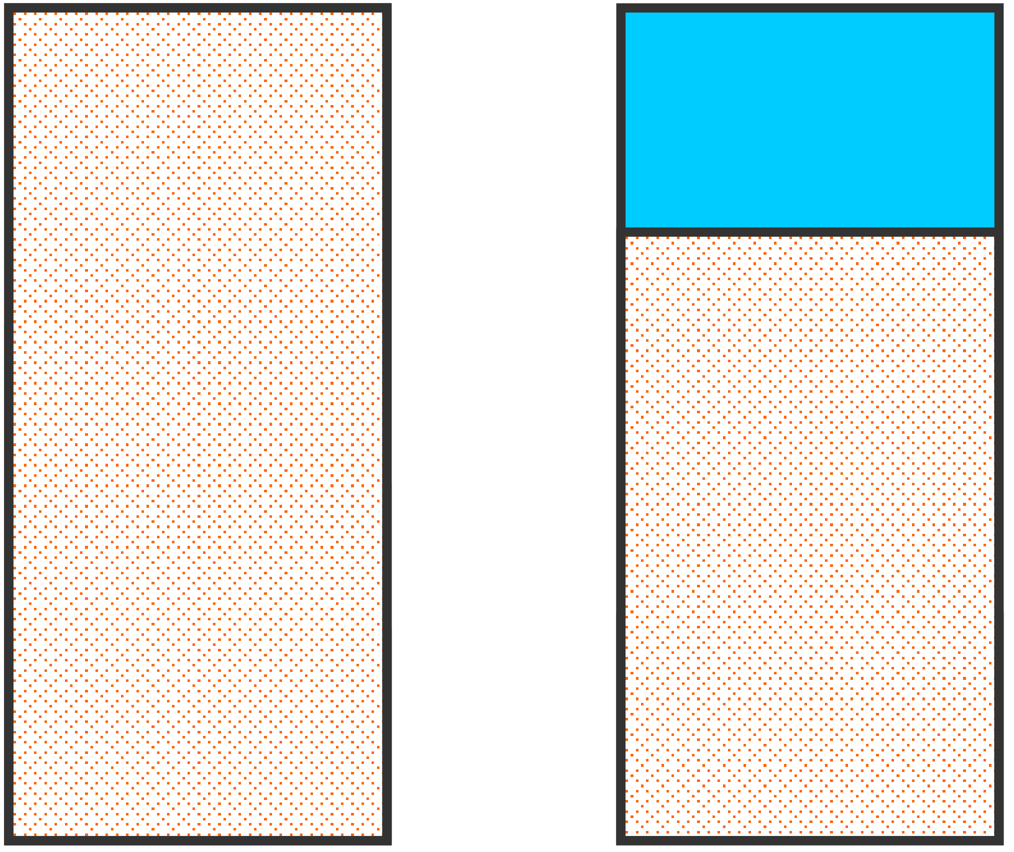
Cement Hydration

- PC + H_2O → CSH + $CaOH_2$
- CaOH + Pozz → CSH


1 15KV 3PM 04.001

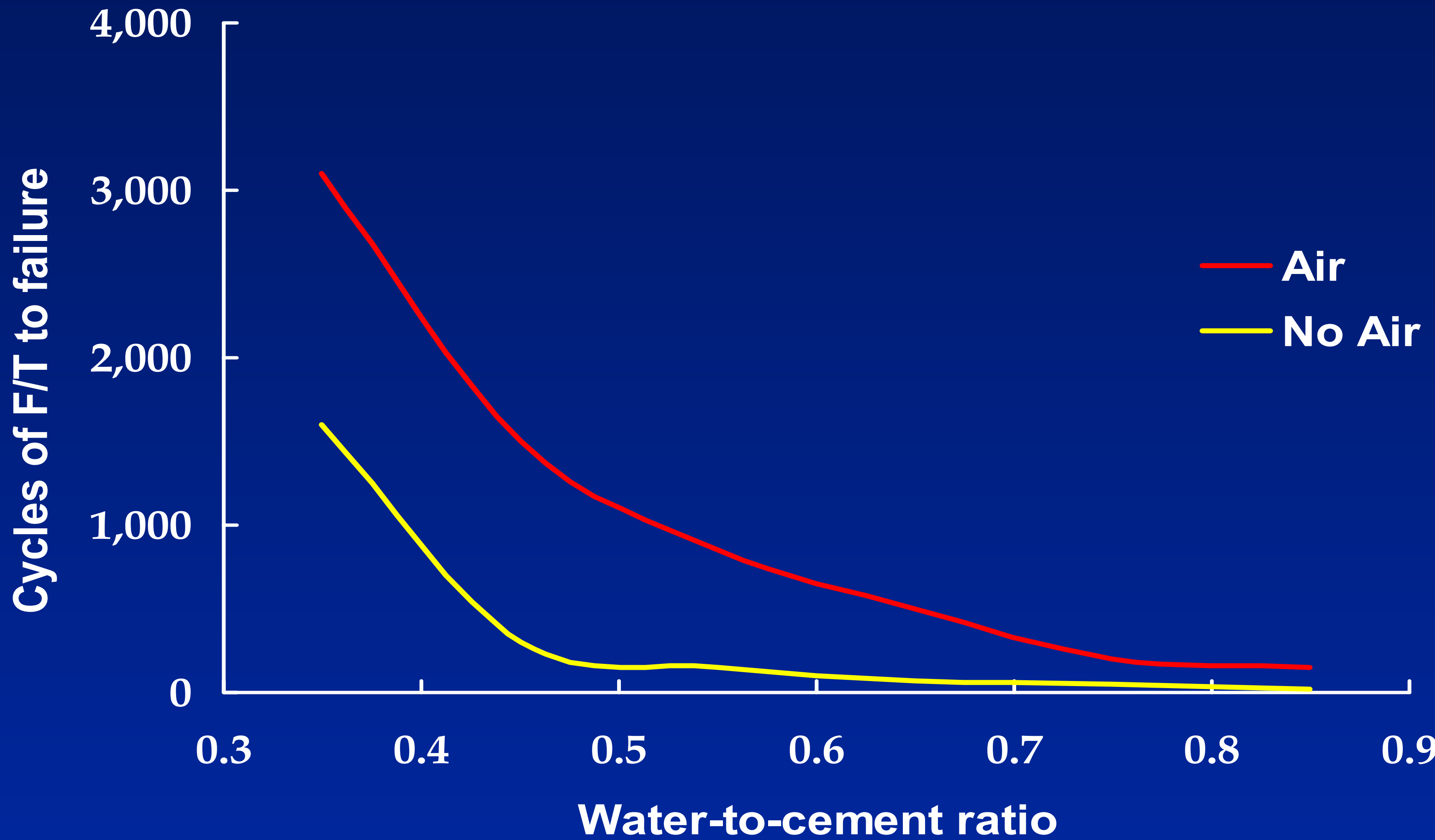

1 15KV 10PM 80.028

Water

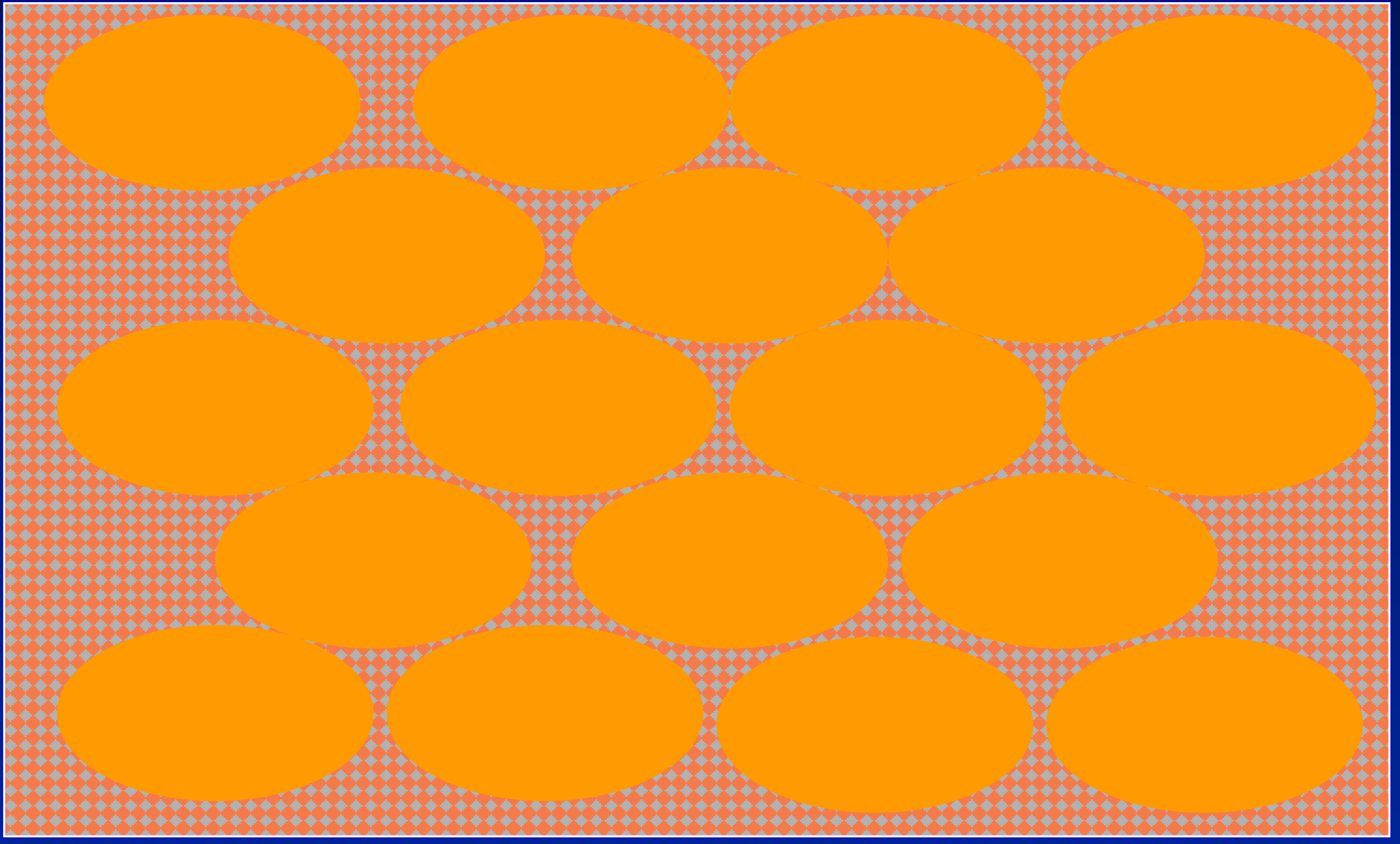


W/C = 0.45 **W/C = 0.75**

Effect of w/c Ratio on F/T Resistance



Aggregates



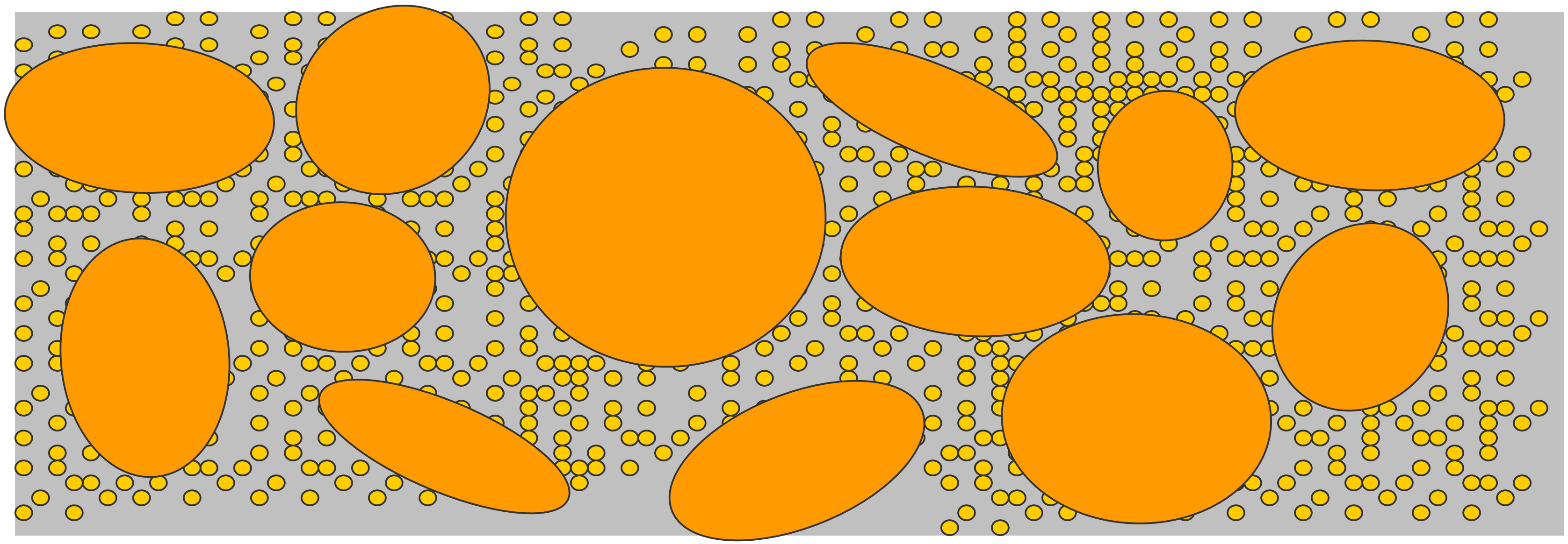
Chemical Admixtures

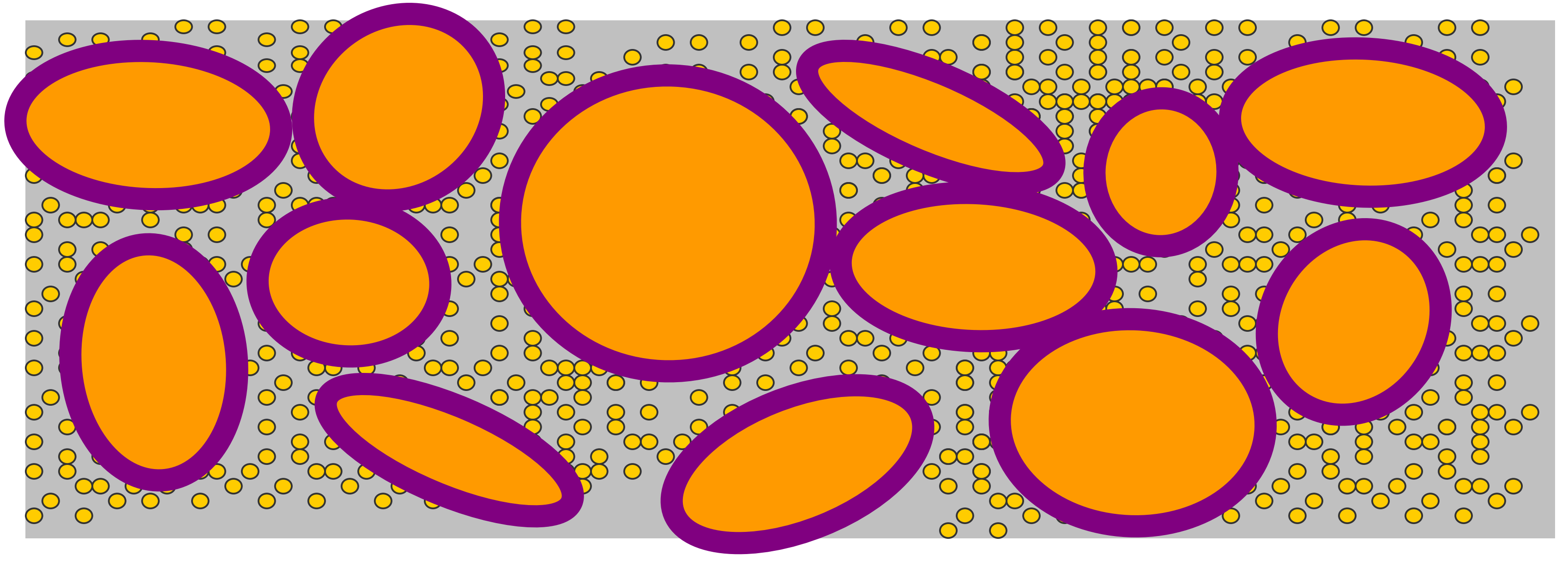
Why Does Concrete Fail?

- Alkali Silica Reaction
- Sulfate Attack
- Frost Related Damage
- Others…

Alkali Silica Reaction

- Water + alkali hydroxide + reactive silicate aggregate → alkali silicates
- Alkali silicates + water → gel + expansion





Sulfate Attack

- Sulfates
- Water
- C_3A

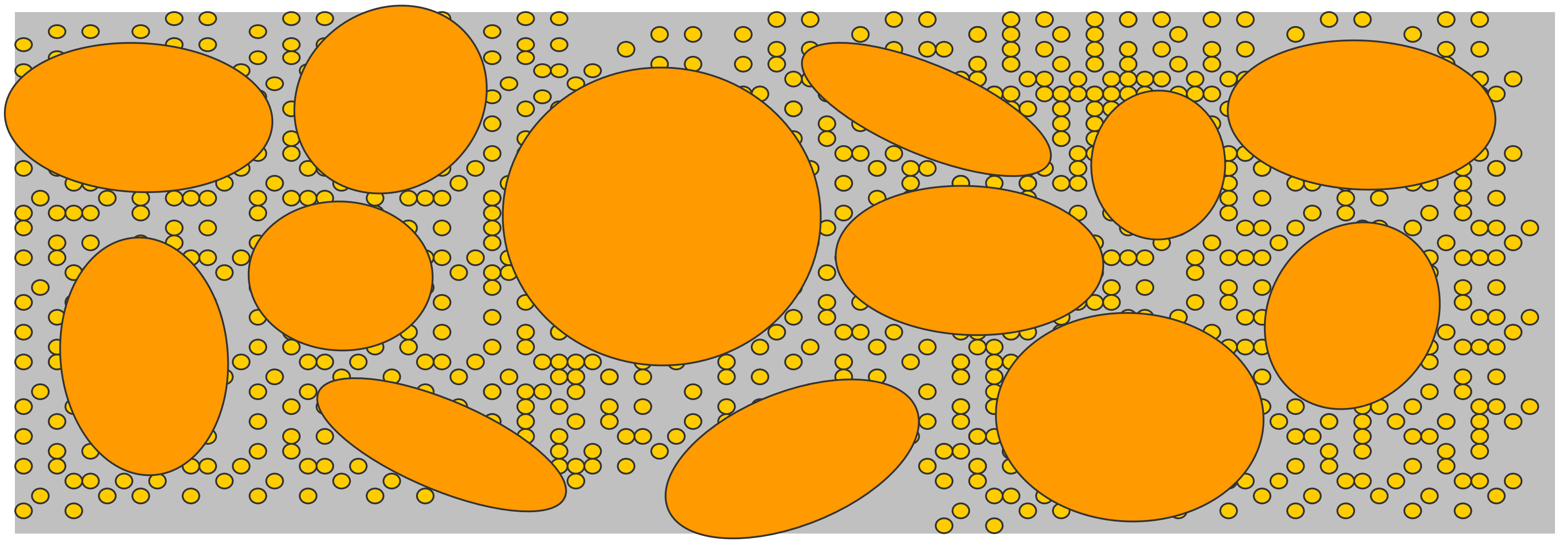
Sulfate Attack

- $C_3A + C' + 12H \rightarrow C_4A'H_{12}$ (monosulfate)
- $C_4A'H_{12} + 2C' + 20H \rightarrow C_6A'_3H_{32}$ (ettringite)
- $Na_2SO_4 + Ca(OH)_2 + 2H_2O \rightarrow 2NaOH + CaSO_4.2H_2O$ (gypsum)

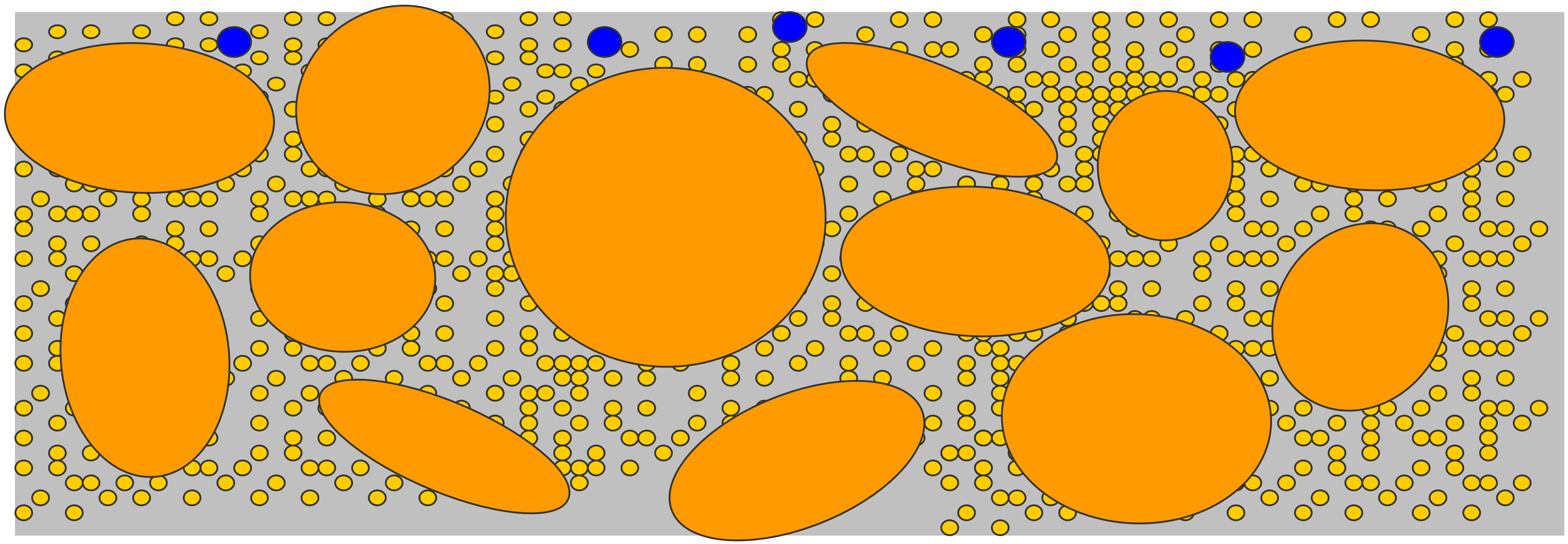
Freeze thaw / Salt scaling

- Cyclic freezing and expansion of water
- Osmotic pressure
- Salt crystallization
- D-Cracking

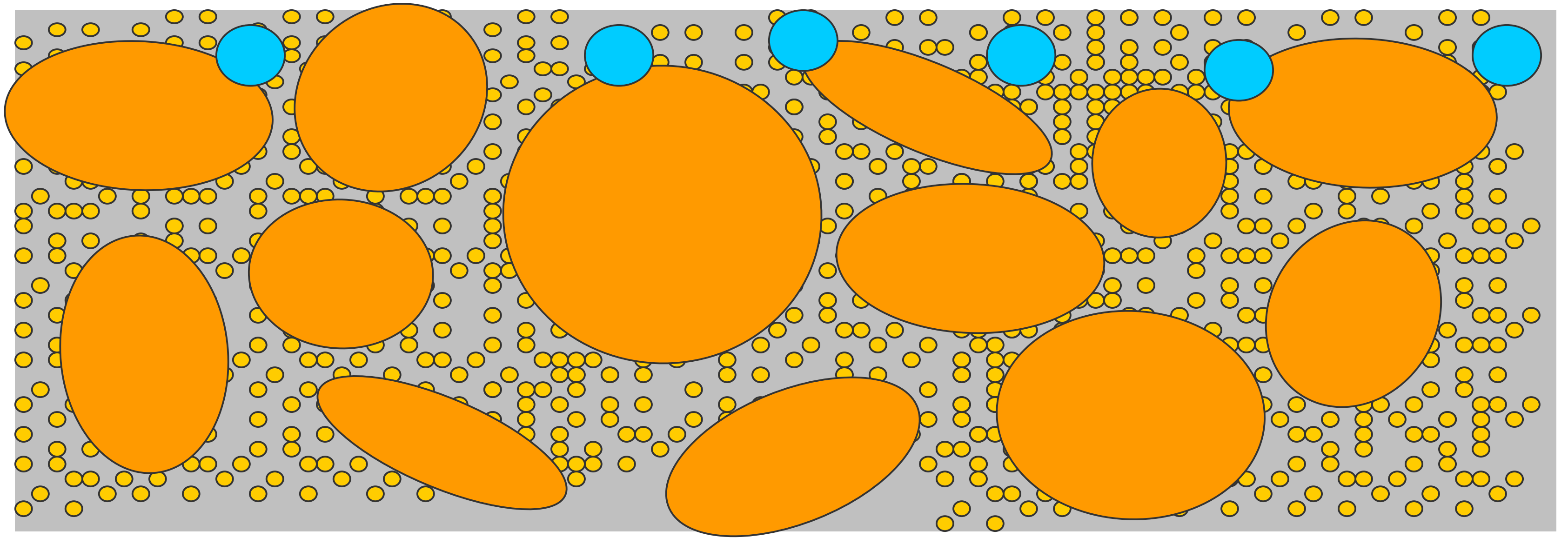
Freeze thaw



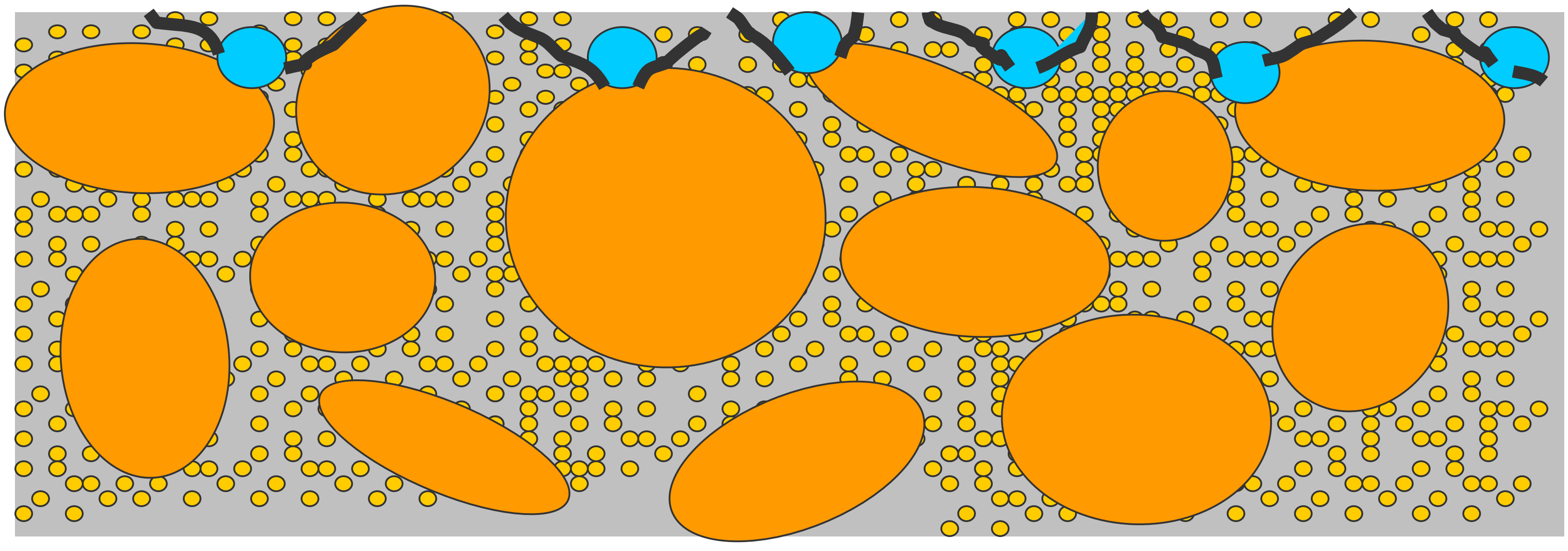
Freeze thaw



Freeze thaw

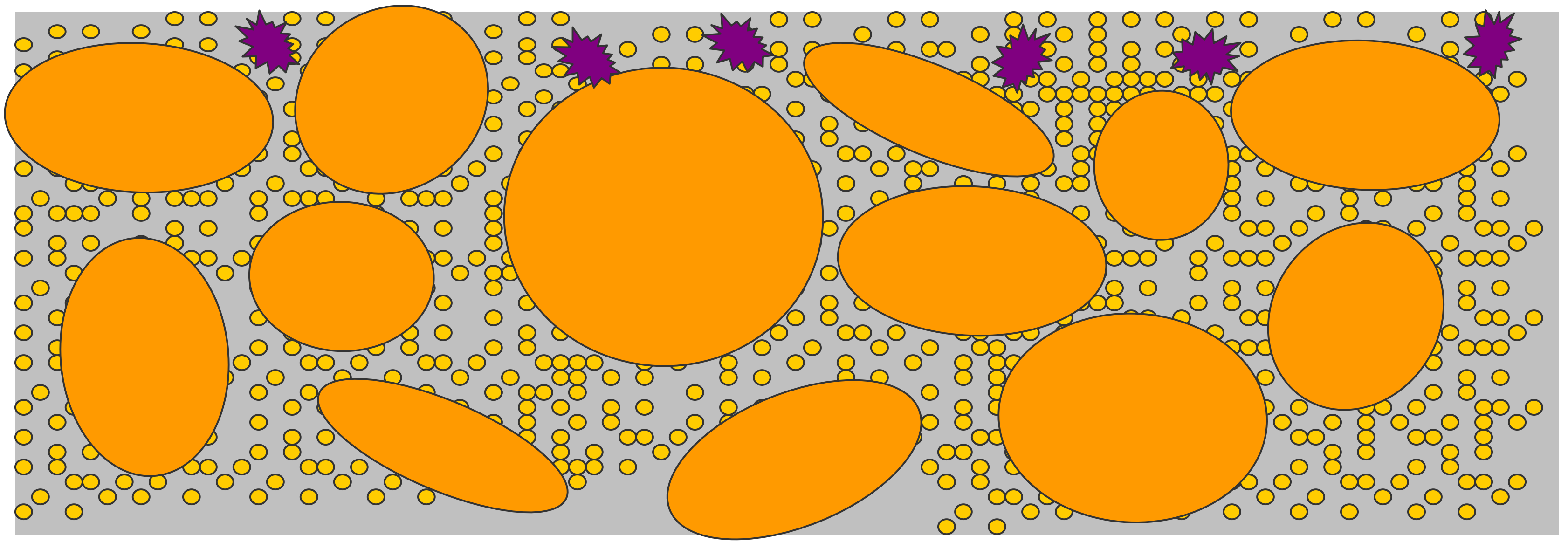


Freeze thaw



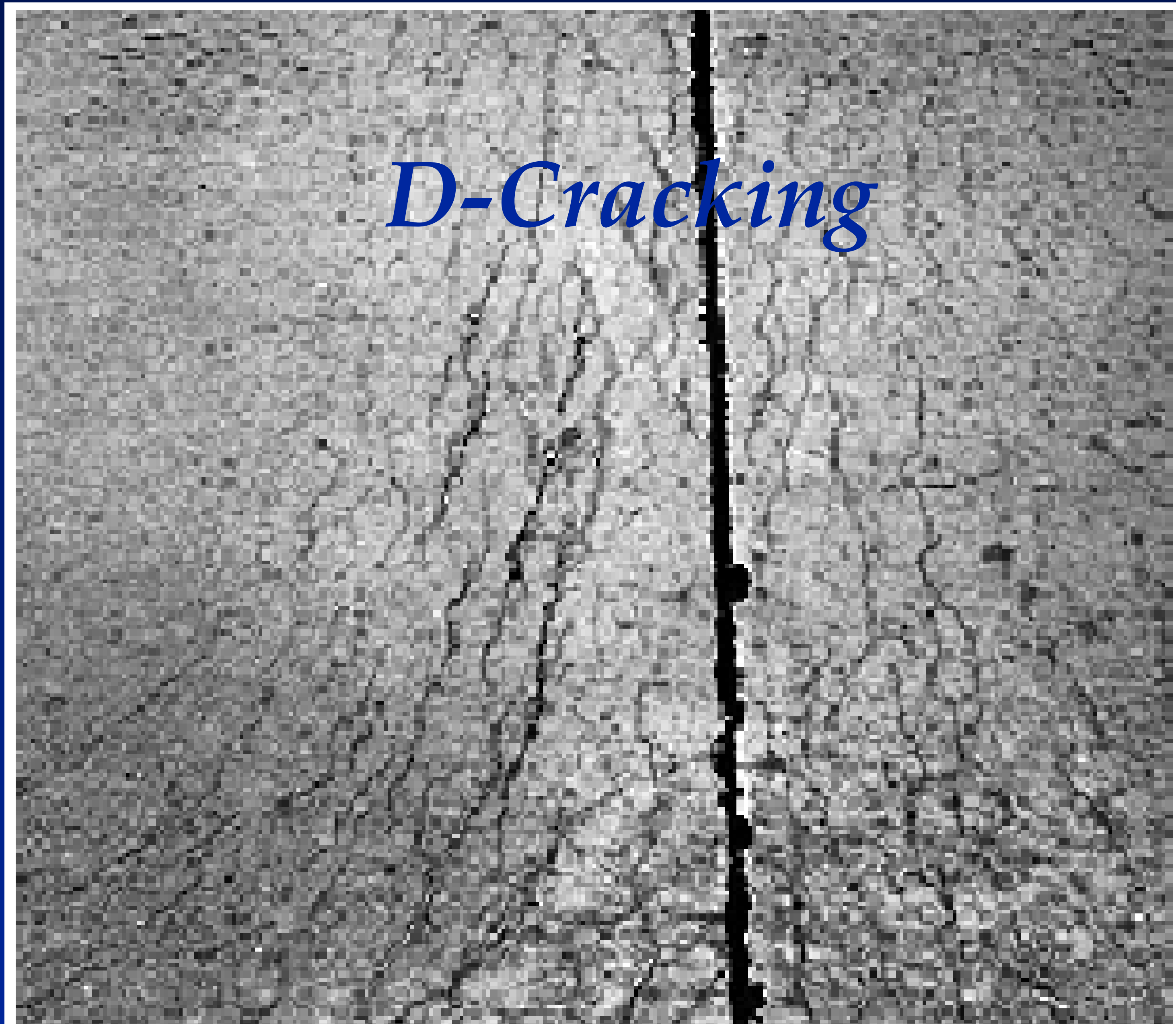
Freeze thaw

Salt Crystallization



Salt Crystallization

D-Cracking

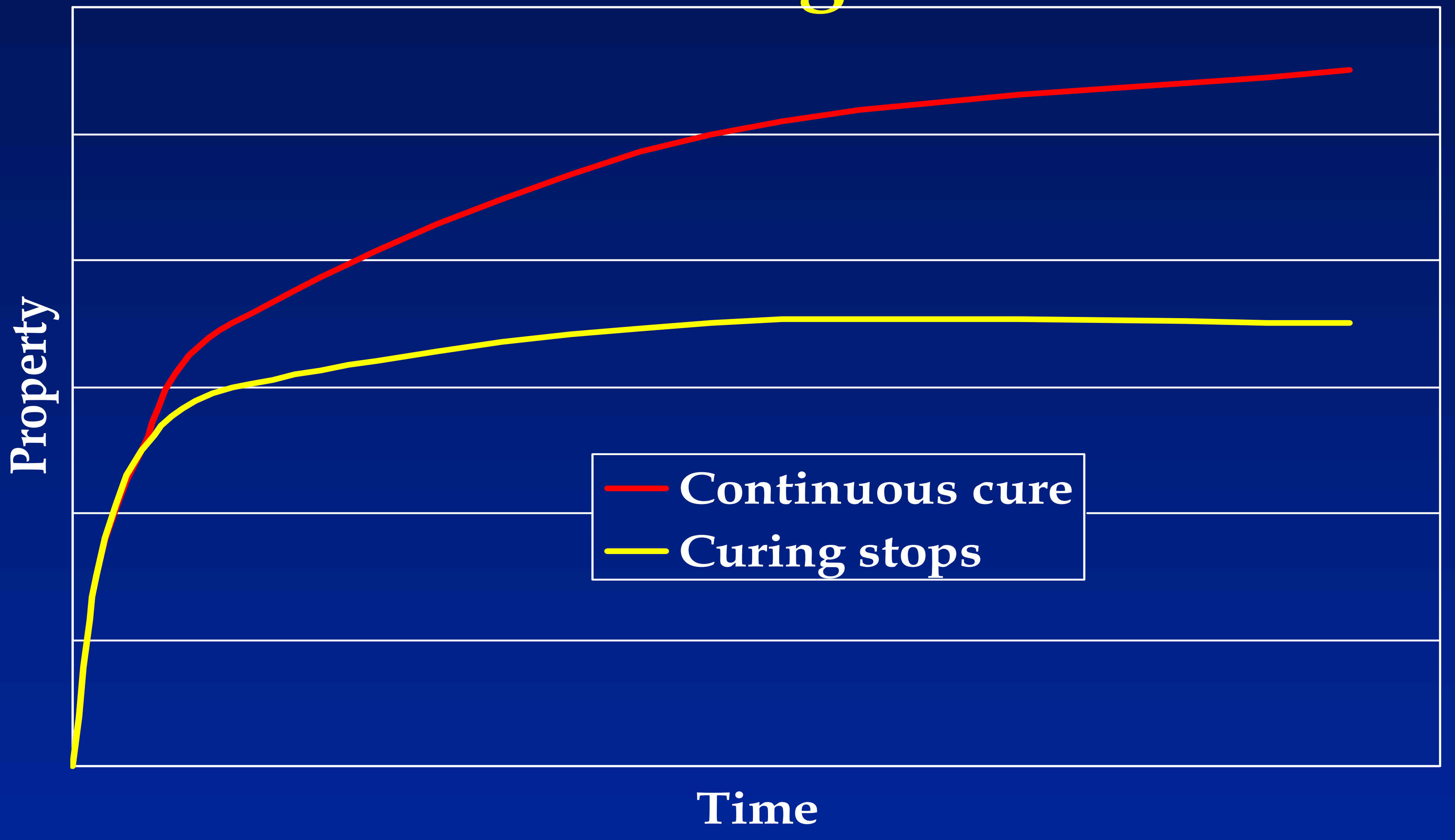


So How Do We Make Our Concrete Survive?

- Understand the environment
- Prevent water from getting in
- Choose the right materials
- Proportion them well
- Use good workmanship

Curing

Curing

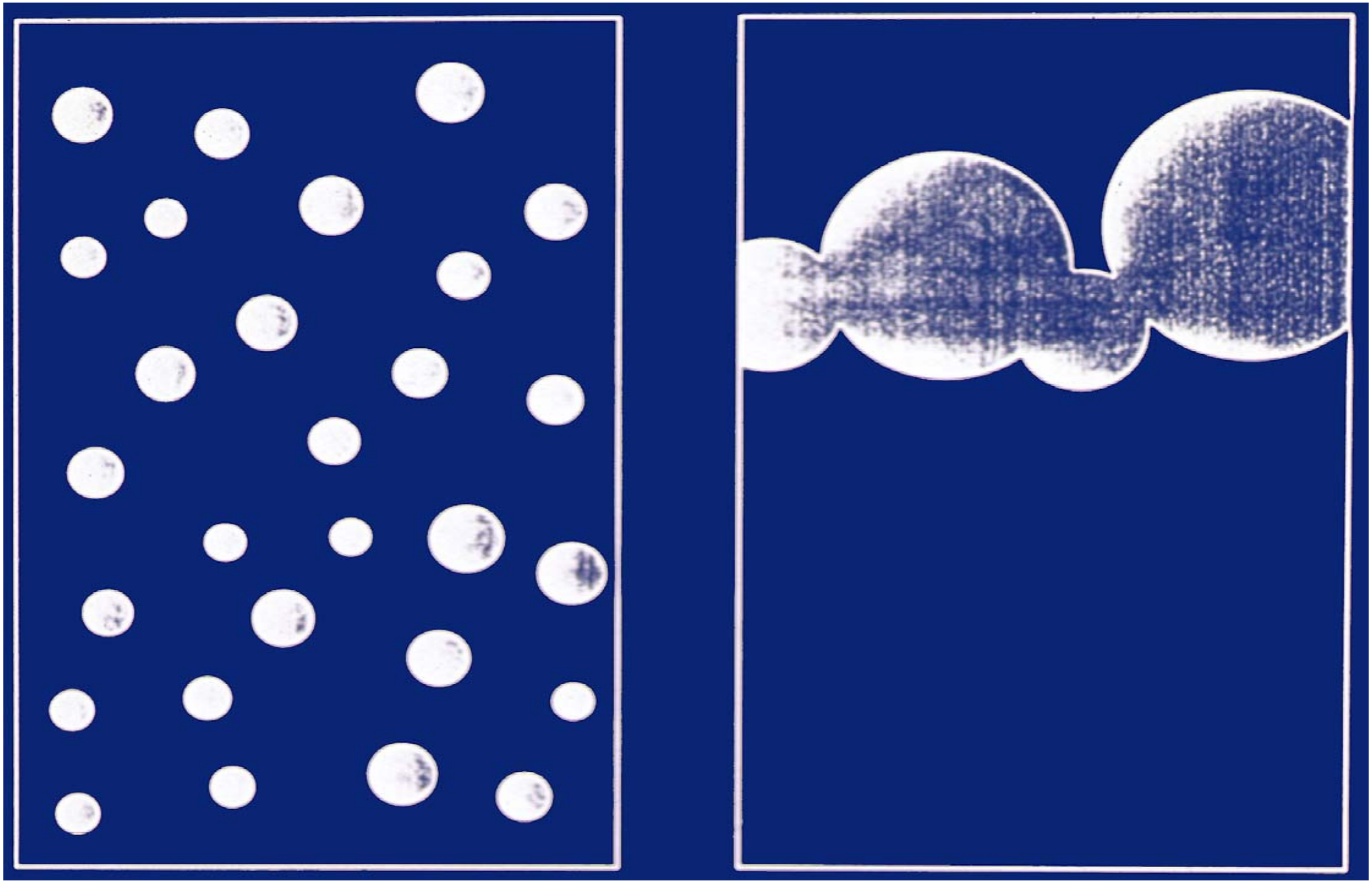


Permeability

- In concrete, low permeability is important for keeping things out:
  - oxygen: steel corrosion
  - water: frost damage, leaching, ASR, corrosion
  - other chemicals: sulfate attack, carbonation

Permeability

- Low water / cement ratio
- High degree of hydration
- Supplementary cementing materials
- Minimize voids
- Minimize cracking



Materials Selection

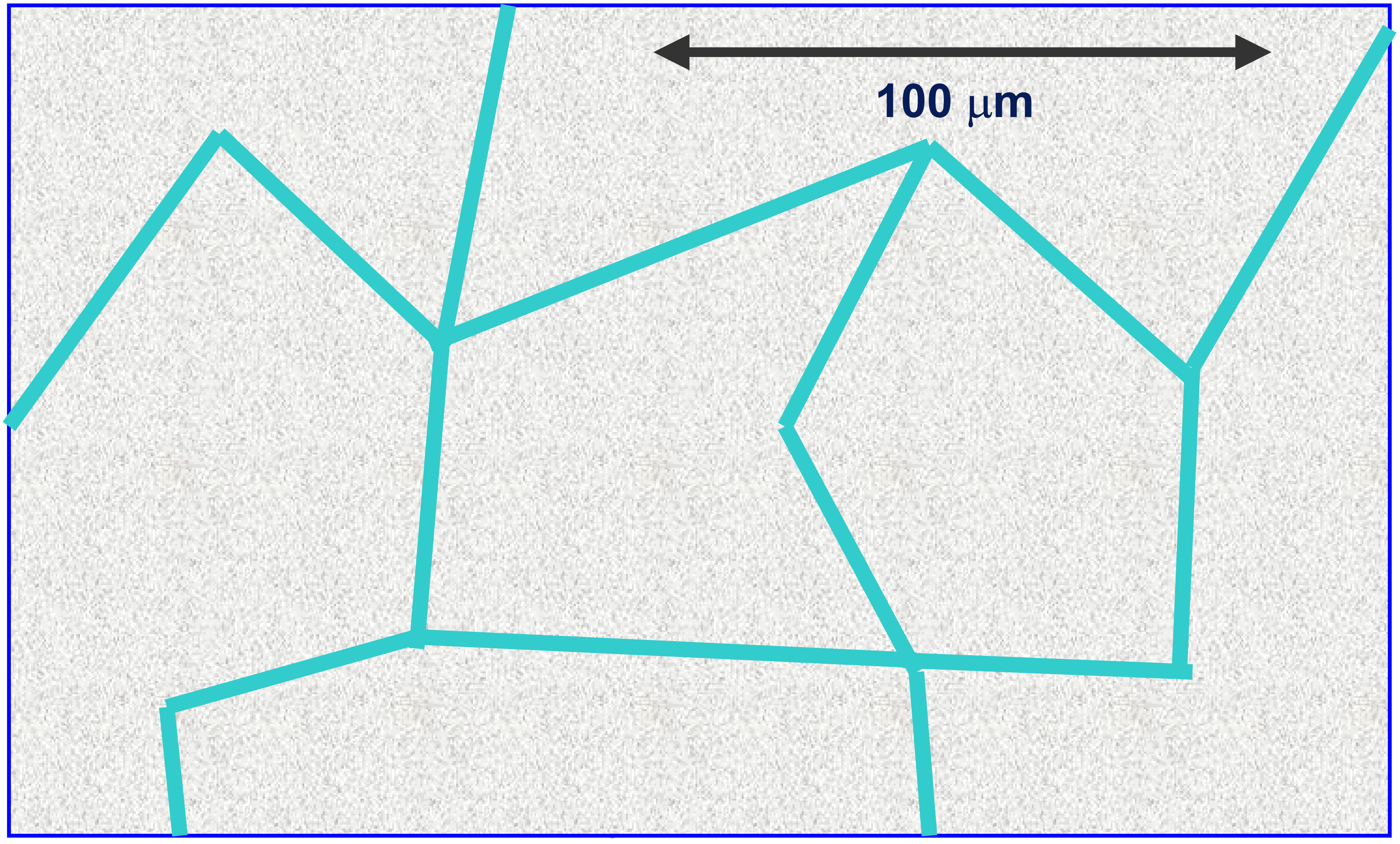
- Alkali-silica reaction
  - Reactive aggregate
  - Fly ash (CaO / SiO_2 ratio)
  - Alkali content of concrete
- Sulfate attack:
  - Cement C_3A content
  - Fly ash

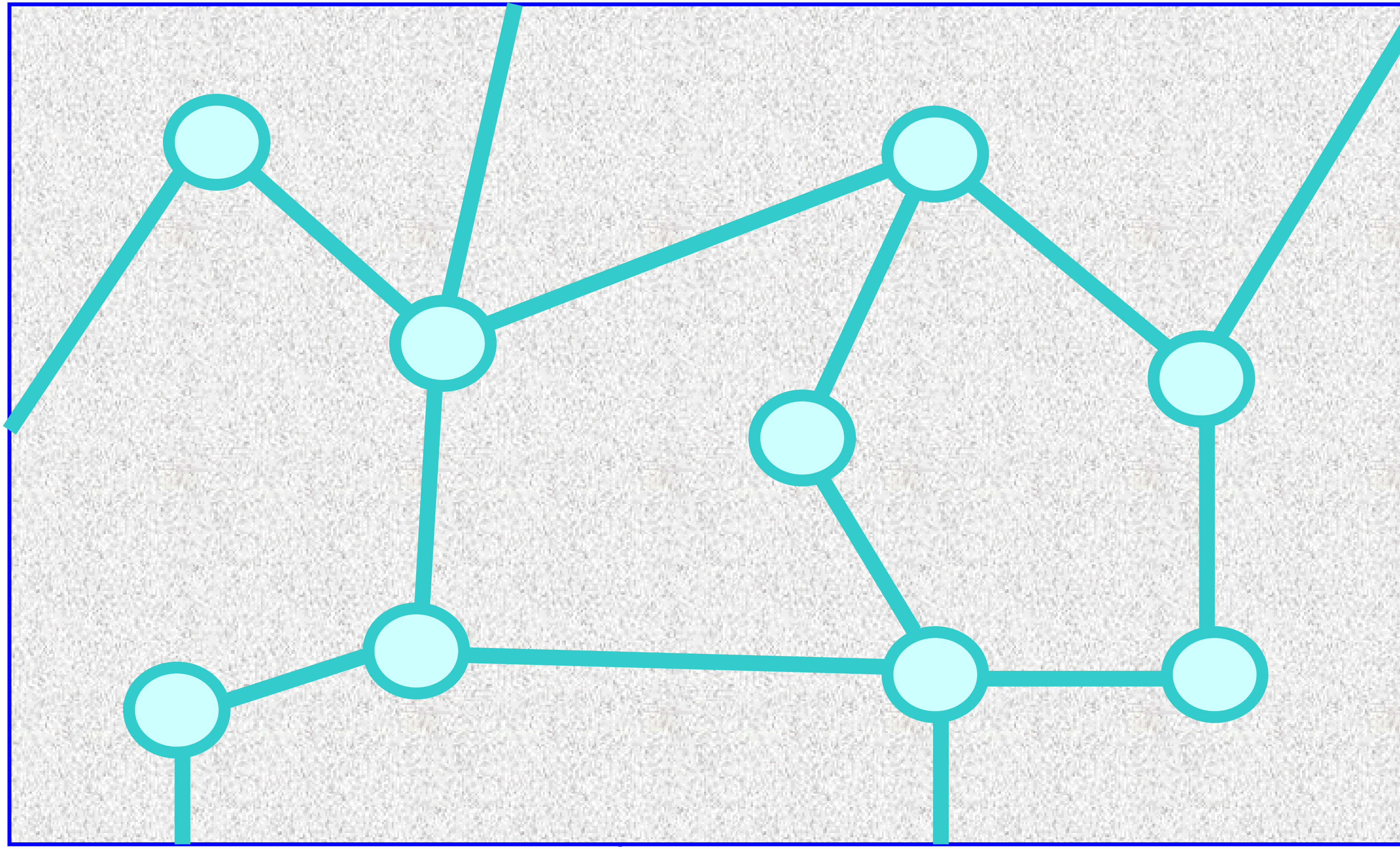
Materials Selection

- Frost Damage
  - D-Cracking – choose smaller size
  - Appropriate air content
  - Supplementary cementing materials

Proportioning

- Minimize paste content
- System grading
- Supplementary cementing materials dosage
- Water cementing materials ratio
- Air content


100 μm



Mixing

- Batching sequence
- Time in the mixer
- Retempering
- Temperature

Placing

- Avoid segregation during transporting
- Ensure adequate compaction
- Protect from the elements
  - Wind
  - Rain
  - Temperature
- Time the joint cutting

Curing

- Start early
- Stay late
- Complete coverage
- Control temperature

Closing

- It is possible to make potentially durable concrete…